

Some aspects of radioecological monitoring of littoral high-aquatic plants from water-bodies within the Chernobyl Accident Exclusion Zone

N. Shevtsova and D. Gudkov

*Institute of Hydrobiology of National Academy of Sciences of Ukraine, Geroyev
Stalingrada ave. 12, Kiev, 04210, Ukraine, shevtsovanl@rambler.ru*

Abstract. Cytogenetic, morphological and reproductive rates of the air-aquatic (13 species) and submerged (2 ones) plants of littoral ecotones from different water bodies within the Chernobyl accident exclusion zone. The absorbed dose rate for littoral emergent plants in sampling water bodies was varied from $1.3\text{E-}02$ to $1.6\text{E-}01$ Gy•year⁻¹. The rate and main types of chromosome aberrations in roots meristems, morphological damages in seed germs for common reed, as well as rates of germinating ability and power were analyzed. There was determined the positive correlation between absorbed dose rate and chromosome aberration. The highest rate of chromosome aberrations (up to 17 %) were registered in plants with high level of morphological deviations in seeds germs. The data obtained from the complex analysis of natural populations of the common reed from the radioactive contaminated water bodies testify about rather high level of genetic efficiency of low doses of long-term exposure. There is observed a realization of radiobiological reactions on morphological and reproductive levels of plants from contaminated water bodies on the background of genetic instability induced by low doses.

1. INTRODUCTION

The investigation of biological effects of long-term irradiation on non-human biota inhabiting the radioactive contaminated territories, has a theoretical and applied importance for ecological hazard understanding, associated with changing of environmental radioactivity state due to human activity. The territory of the Chernobyl accident Exclusion Zone gives a unique opportunity to examine state of flora and fauna in conditions of man-made radioactive anomaly. After the Chernobyl NPP accident within the inner (10-km) Exclusion Zone the numerous of morphological anomalies, such as juvenility or sterility of reproductive organs, excessive bifurcation, decrease of parasitical resistance etc, are registered for terrestrial plants [1, 2]. Since 2000 the increase of common reed damage by gall-producing arthropods (mainly by mites of *Tarsonemidae* family) is observed [3]. Also, the genetic test-systems are the most reliable and sensitive parameters of the damage processes for biota within radioactive contaminated areas. So, the main aim of our studies was to investigate cytogenetic, morphological and reproductive rates of the of the dominant species of littoral cenosis common reed *Phragmites australis* (Cav.) Trin. ex. Steud. and some another dominant and subdominant

species of higher-aquatic plants from different water bodies within the Chernobyl accident exclusion zone

2. MATERIALS AND METHODS

Our research was carried out during 2006-2010 in water bodies within the 30-km Exclusion Zone of the Chernobyl NPP. Sampling of higher aquatic plants for cytogenetic and morphological analysis, and measurement of radionuclide content were carried out within the littoral zone of Azbuchin Lake, Yanovsky (Pripyatsky) Crawl, cooling pond of the Chernobyl NPP, the lakes of the left-bank dammed flood plain of the Pripyat River - Glubokoye Lake and Dalekoye-1 Lake as well as Uzh River (near by Cherevach village) and Pripyat River (near by Chernobyl town). For comparison the sampling station with background radiation - Goloseevo Lake, located within the Kiev City area, was used. External dose rate due to gamma-irradiation was measured by the field radiometers DKS-01 and SRP-68-03. Internal absorbed dose rate was estimated from radionuclides ^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239+240}\text{Pu}$ and ^{241}Am with use of dose conversion coefficients [4].

The rate and main types of chromosome aberrations in roots meristems of 15 species of high aquatic plants and morphological damages in seed germs, as well as rates of germinating ability and power of common reed (*Phragmites australis* (Cav.) Trin. ex. Steud) were analyzed. Common reed belongs to the graminoid family of the monocotyledonous class of the seed plants. It is a perennial plant that clones by rootstocks and reproduces by seeds. Germinating ability, germinating power and morphological damages of the seeds were estimated in accordance with the generally accepted botanical methods [5]. The rate of chromosome aberrations was studied in the apical root meristems of common reed by the modified for macrophytes anaphase method [6].

3. RESULTS AND ANALYSIS

The values of the absorbed dose for higher aquatic plants from water bodies of the Chernobyl Exclusion Zone were found to be in the range from 0,0018 to 0,16 Gy·year⁻¹. The highest value was found for hydrobionts from lakes within embankment territory on the left-bank flood plain of Pripyat River, the lowest – for specimens from the running water objects – Uzh River and Pripyat River (Table 1).

According to the classification of G.G. Polikarpov [8], the studied littoral sites of Uzh and Pripyat rivers belongs to the radiation safety zone; the sampling stations of Azbuchin Lake, Yanovsky Crawl, the Chernobyl NPP cooling pond and Dalekoye-1 Lake are zones of physiological and ecological disguise, where the radiobiological effects are difficult to detect due to the influence of other ecological factors. Glubokoye Lake approaches to the ecosystem of effect zone where reduction in aquatic organism numbers and loss of radiosensitive species can be observed.

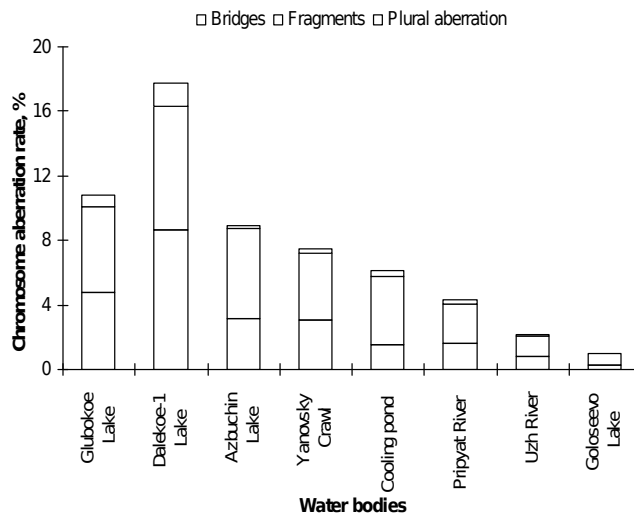
Table 1. Ranges for the absorbed dose rate for higher aquatic plants of littoral zone of water bodies within the sampling sites, Gy year⁻¹

Water bodies	External γ -dose	Internal dose from incorporated radionuclides	Total dose
Glubokoe Lake	4.0E-02 – 4.2E-02	3.9E-02 – 1.2E-01	7.9E-02 – 1.6E-01
Dalekoe-1 Lake	2.5E-02 – 2.9E-02	8.5E-03 – 4.2E-02	3.4E-02 – 7.1E-02
Azbuchin Lake	3.8E-03 – 4.2E-03	1.3E-02 – 6.8E-02	1.7E-02 – 7.2E-02
Yanovsky Crawl	1.2E-02 – 1.3E-02	4.2E-03 – 4.4E-02	1.6E-02 – 5.7E-02
Cooling pond	7.1E-03 – 8.2E-03	6.0E-03 – 2.3E-02	1.3E-02 – 3.1E-02
Pripyat River	2.3E-03 – 3.6E-03	1.40E-04 – 5.4E-04	2.4E-03 – 4.1E-03
Uzh River	1.7E-03 – 2.9E-03	1.1E-04 – 3.6E-04	1.8E-03 – 3.3E-03
Goloseevo Lake	2.1E-04 – 2.6E-04	0.5E-04 – 1.3E-04	2.6E-04 – 3.9E-04

Common reed is the most widespread and mass-grow species of the helophytes (aerial-aquatic plants) within the Chernobyl Exclusion Zone and background radioactivity water body. We have analysed 8987 root cells from 87 plants and measured 721 aberration cells and 781 aberrations.

The spontaneous rate of aberrant cells for hydrobionts does not increase 2 % [9]. We found 4.5 % aberrant cells in common reed of the Pripyat River, and 2.2 % in the Uzh River. More high level were registered in the cooling ponds of the Chernobyl NPP and Yanovsky Crawl - 6.1 % and 7.5 % respectively. Maximum rate of chromosome aberration was registered in plants from Azbuchin, Glubokoe and Dalekoe-1 lakes - 9.0 %, 10.8 % and 17.8 %, respectively. In comparison, the data received for reed from Goloseevo Lake amount to 1.0 %. The rate of chromosome aberration in reed from closed water bodies within the left-banked flood plain of the Pripyat River was in 5-8 times higher than spontaneous mutagenesis level.

As shown in Fig. 1a. the single fragments were the frequently occurring aberration in meristem cells of reed - 57.1 % of all aberrations. Rate of single bridges were 40.7 %, plural aberration, including different variation of fragments



and/or bridges (pair bridges or fragments, bridge and fragment, bridge and two fragments, three fragments) were 2, 3%.

a) b)
Figure 1. Spectrum of the main chromosome aberration in meristem cells of the common reed from water bodies within the Chernobyl accident Exclusion Zone: a) 2006; b) 2010

It seems that spectrum of the main types of chromosome damages in plants of water bodies of the right-bank flood plain of Pripjat River determines by the chemical mutagens (up to 69 % of single fragments). In 2006 the type of chromosome damages distribution in plants from lakes within embankment territory on the left-bank flood plain of the Pripjat River points to practically equivalent effects of radiation and chemical factors - 44-49 % of bridges, 43-50 % of fragments and 6-8 % of multiaberrations. As for 2010 the part of multi-aberrant cells dramatically increased (Figure 1b).

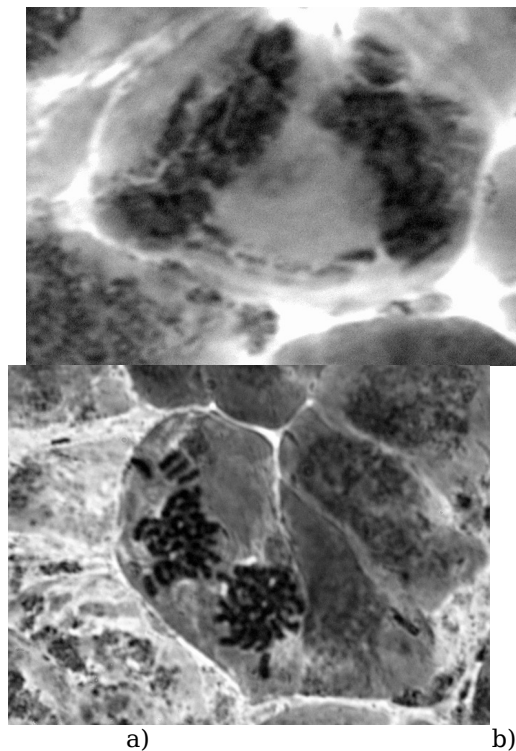


Figure 2. Chromosomal aberrations in root meristem cells of the arrowhead *Sagittaria sagittifolia* L. from water bodies within the Chernobyl accident Exclusion Zone: a) double bridge; b) multi-aberrant cell

The studies of the different species of plants within the exclusion zone has revealed a numerous morphological anomalies as repeated organs, gigantism or dwarf, underdevelopment or sterility of reproductive organs, excessive branching, growth inhibition of the secondary points of growth etc [2,3]. All of this variety of

plant anomalies of development is testify that the vegetation within the exclusion zone has undergone to strong damage of the genotype, which consequence is the long genetic instability and thus increased variability of many species.

Performed studies indicate the existence of authentic morphometric and morphological abnormalities of reproductive organs of the common reed within the Chernobyl Exclusion Zone. The most typical abnormalities are decreasing of average reed panicle length and width; decreasing of the number of flowers of a low-level blossom cluster and also modification of the shape and colour of the seeds in comparison with standard parameters for the common reed of Europe's middle latitude.

Analysis of the morphometric characteristics of the common reed panicles displays certain deviation connected with reed growth location (Table 2).

Table 2. Morphometric characteristics of the common reed panicles sampled within the range of the Chernobyl Exclusion Zone

Water body	Number of investigated panicles	Average length of the panicle, cm	Average width of the panicle, cm	Number of flowers of low-level blossom cluster
Cooling pond	18	28.7±1.4	5.4±0.2	3-4
Yanovsky Crawl	16	30.0±1.5	4.8±0.2	3-4
Azbuchin Lake	22	26.4±1.3	6.1±0.3	4-6
Dalekoe-1 Lake	15	23.7±1.1	3.1±0.1	2-3
Glubokoe Lake	16	19.9±0.9	2.7±0.1	2-3

It is known that common reed's panicles length and width vary from 20 to 50 cm and 10-25 accordingly and number of a low-level blossom cluster also vary from 3 to 7. Thus average morphometric characteristics of the reed's panicles sampled from the water bodies within the Exclusion Zone refer to minimal of the normal reed plant but average width is lesser than normal reed plant has. Furthermore the number of flowers of a low-level blossom cluster is more often 2 then 3 for the common reed sampled from the water bodies within the Exclusion Zone.

Correlation analysis showed direct dependence between variation of the reed panicle characteristics variation and absorbed dose rate of the ionizing radiation. Thus the Pirson correlation coefficient for the number of flowers of a low-level blossom cluster and absorbed dose rate of the ionizing radiation was 0.89 and error coefficient was 0.068.

Essential divergence for morphometric characteristics of the common reed seeds was not discovered. But patience should be paid to the shape and colour of the reed's seeds sampled from lakes Dalekoe-1 and Glubokoe that have highest radionuclide contamination within the range of the Chernobyl Exclusion Zone (Table 2). Such abnormalities could be interpreted as radiomorphoses, which also were registered for some species of cultural graminoid, for example for fall wheat [3].

Table 3. Morphometric characteristic of the common reed seeds, sampled within the Chernobyl Exclusion Zone

Water body	Number of seeds	Average morphometric characteristics				Shape	Color
		length, mm	width, mm	volume, mm ³	mass, mg		
Chernobyl NPP cooling pond	32765	3.2	0.9	1.5	0.13	pillow-like smooth	sandy
Yanovsky Crawl	35478	2.9	0.9	1.4	0.10	pear-shaped, hilly	sandy
Azbuchin Lake	36574	2.9	1.1	1.9	0.11	pillow-like smooth	brown
Dalekoe-1 Lake	32879	2.9	1.0	1.5	0.12	tear-shaped, plicate	brown
Glubokoe Lake	28764	2.9	1.0	1.5	0.11	tear-shaped, plicate	dark brown

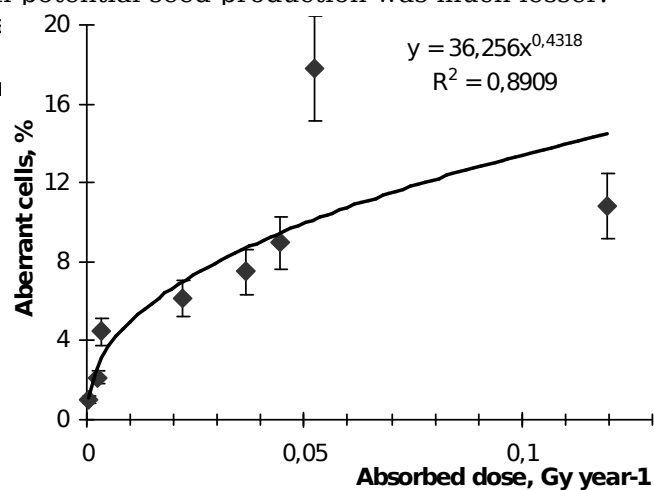
Also parameters of the common reed seed potential production, effective seed output and panicle sterility were studied (Table 4).

Table 4. Average parameters of seed productivity of common reed from water-bodies within the Chernobyl Exclusion Zone

Water body	Potential seed production, seeds per panicle	Panicle sterility ratio, %	Effective seed output, %
Chernobyl NPP cooling pond	4200±28	53,1±0,1	41,8±0,1
Yanovsky Crawl	4130±25	64,1±0,2	32,0±0,2
Azbuchin Lake	5527±32	29,4±0,1	69,9±0,1
Dalekoe-1 Lake	2572±12	71,7±0,1	6,6±0,1
Glubokoe Lake	2116±10	47,5±0,1	6,8,0±0,3

Relation of potential seed production and effective seed output is one of the significant parameter characterizing rate of reproductive performance suppression of plant. Thus for the cultural cereal explorers observed complete or partial sterility [2, 3] but for the common reed we found that panicle sterility ratio does not exceed 72 percents. In normal case 1 panicle produces about 5,000 viable seeds [10] but in our case even potential seed production was much lesser.

There were no chromosome bodies (Fig. 1) registered in



sorbed dose rate and from sampling water is (up to 17 %) were in seeds germs.

Figure 3. The dependence of chromosome aberration rate from absorbed rate in cells of common reed from water bodies within the Chernobyl Exclusion Zone.

4. CONCLUSIONS

An increasing importance of the genetic damages induced by a long-term irradiation is expected. These remote consequences are delayed manifestation of changes in germ cells, where the initial molecular damages have a latent period, without any evident effect, but can be transferred through many generations of cells to trigger genome instability in future. The long-term impact of low dose irradiation in aquatic ecosystems, especially in closed water bodies within the Chernobyl Exclusion Zone, is shown by the increased level of chromosome aberrations and concerned different morphological anomalies and decreasing of reproductive ability.

REFERENCES

- [1] Grodzinsky, D.M., K.D. Kolomiets, Yu.A. Kutlakhmedov et al., 1991. Anthropogenic radioactive anomaly and plants, Lybid', Kiev (Rus).
- [2] Grodzinsky, D.M., K.D. Kolomiets and O.D. Burdenyuk, 2000. Mutagenesis of plants in the Exclusion Zone. Bulletin of the Ecological Condition of the Exclusion Zone and the Zone of Absolute Resettlement, 16, pp.50-54 (Ukr).
- [3] Gudkov, D.I., C.F. Uzhevskaya, A.B. Nazarov et al., 2006. Lesion in common reed by gall-producing arthropods in water bodies of the Chernobyl NPP exclusion zone. Hydrobiological Journal, 1, pp.82-88.
- [4] Brown, J., P. Strand, A. Hosseini and P. Borretzen, 2003. Handbook for assessment of the exposure of biota to ionising radiation from radionuclides in the environment. A project within the EC 5th Framework Programme.
- [5] Demidovskaya, L.F. and R.A. Kirichenko, 1964. Morphological characteristics of the common reed. Proceedings of the Institute of Botany of the Kazakhstan Academy of Sciences, 19, pp.109-135.
- [6] Shevtsova N.L., Gudkov D.I., Stoyko U.A., Syvak E.V., 2005. To the method of determination of chromosome damages of higher aquatic plants at the example of common reed and arrowhead. Scientific Acta of the Ternopil State Teacher's Training University, 3, pp. 478-479 (Rus).
- [7] Gudkov, D., N. Shevtsova, O. Dzyubenko et al., 2006. Dose rates and effects of chronic environmental radiation on hydrobionts within the Chernobyl exclusion zone. - Radiation risk estimation in normal and emergency situations. - Springer, pp. 69-76.

- [8] Polikarpov, G.G., 1998. Conceptual model of responses of organisms, populations and ecosystems in all possible dose rates of ionising radiation in the environment. *Radiation Protection Dosimetry*, 1-4, pp. 181-185.
- [9] Tsytsugina, V.G., 1998. An indicator of radiation effects in natural populations of aquatic organisms. *Radiat.Protect.Dosim*, 1pp. 171-173.
- [10] Dubina, D.V., S.M. Stoyko, K.M. Sytnik et al., 1993. Macrophytes - indicators of environmental changes. *Naukova Dumka*. Kiev (Rus).